MUNDRABILLA'S ANOMALOUS MACROSTRUCTURAL FEATURES REVEALED AS MICROGRAVITY CAST STRUCTURES BASED ON CLASSICAL SOLIDIFICATION PRINCIPLES.

P.Z. Budka[1], J.R.M. Viertl[2], S.V. Thamboo[3], R.E.LaRose[4], [1](2135 Morrow Ave., Schenectady, NY 12309 e-mail: 75302.1764@compuserve.com), [2](1403 Clifton Park Rd., Schenectady, NY 12309).

Mundrabilla, considered structurally anomalous within the population of medium octahedrites, is rich in both sulfur (8%) and carbon (1%) (Buchwald 1975). Mundrabilla's first major anomaly, immediately visible to the naked eye, is that Widmanstätten areas are rounded and encased in troilite; troilite encased by the Widmanstätten structure is more typical for nickel-iron meteorites. The second major anomaly is the presence of "graphite fans;" the fan in our 12.7 x 8.4 x 1.8 cm, 1378.3 gram specimen is 13 x 10 mm. While cast irons and meteorites share many graphite morphologies in common, Mundrabilla's well-developed graphite fans are striking and unusual even among the group of meteoritic graphite morphologies.

Mundrabilla's macrostructural features are consistent with those of a casting which solidified under microgravity conditions in a relatively shallow thermal gradient (Budka and Viertl 1993). Since some Fe-Ni alloys can undercool up to 175K (Abbaschian and Flemings (1993), the Mundrabilla melt may have experienced significant undercooling before the onset of solidification. Multiple nucleation sites, such as those exhibited by Mundrabilla, are characteristic of an undercooled melt.

Anomalous Structure #1: The Widmanstätten areas encased in troilite can be interpreted as evolving from a monotectic reaction (Elliott 1983):

Liquid 1 ---> Solid 1 + Liquid 2.

Characteristics of a monotectic reaction are
- Liquid 1 and Liquid 2 are immiscible.
- Liquid 2 is present in a relatively smaller volume fraction than Liquid 1.
- Liquid 2 solidifies later and at a lower temperature than Liquid 1.

The final morphology of a monotectic reaction depends on the relative surface energies among Solid 1, Liquid 1 and Liquid 2 and their relative volume fractions. On earth, the monotectic microstructural fabric is also influenced by density differences; in microgravity, density differences are very small.

During solidification, the Fe-Ni-S Mundrabilla melt (Liquid 1) reaches the monotectic temperature, Tm. At Tm , Solid 1 (Widmanstätten structure) forms along with Liquid 2 (troilite-rich liquid). Liquid 2 solidifies at a lower temperature. Mundrabilla's high sulfur content (8% versus the more usual meteoritic concentrations of 0.2-1%) resulted in a very high volume fraction of Liquid 2, high enough to reverse the typical surface energy/wetting relationship between Widmanstätten and troilite regions.

Anomalous Structure #2: Mundrabilla's kamacite/graphite fans grew from a liquid locally enriched in Fe-Ni-C. The resultant two-phase solid is similar to the eutectic colony structure described in (Chalmers 1977). Undercooling, a shallow thermal gradient and impurity elements promote colony structure growth.

Our specimen contains 9 kamacite/graphite eutectic colonies in an area of 106.7 cm^2; only one is a distinct fan. These colonies are typically found within the Widmanstätten regions; a distinct kamacite interface usually surrounds the colony. The kamacite/graphite eutectic colonies may be "secondary inclusions" formed as pools of impurity elements rejected by the major phase during solidification. The secondary inclusions become isolated pools of liquid within the solidified Widmanstätten structure; the secondary inclusion/eutectic colonies then solidify as separate, isolated castings (Flemings 1974).

In summary, Mundrabilla's major macrostructural anomalies can be simply and successfully interpreted using classical solidification principles coupled with the proposed scenario: microgravity, a shallow thermal gradient and undercooling.

References:

Abbaschian, G.J. and Flemings,M.C., Met. Trans. A Vol. 14A (1993) 1147-1157.

Buchwald, V.F., "Handbook of Iron Meteorites," (1975) 858-862.

Budka, P.Z. and Viertl, J.R.M., "Meteoritics," Vol. 28 No. 3, (1993) 333.

Chalmers, B., "Principles of Solidification," (1977) 126-229.

Elliott, R., "Eutectic Solidification Processing," (1983) 298-302.

Flemings, M.C., "Solidification Processing," (1974) 191-203.